CANONICAL

Ubuntu Core - Security

Whitepaper

CANONICAL UBUNTU ENGINEERING AND SERVICES

Version: 3.0.0 - 2018-11-01

Abstract

Ubuntu Core is an important revolutionary step for Ubuntu. While it builds upon Linux traditions, Ubuntu Core provides a sharp focus on predictability, reliability and security while at the same time enabling developer freedom and control.

Problem

The Linux distribution model is an established and well understood model for computing systems: start with a Linux kernel and some low-level software to install, manage and use applications and then add some default applications with additional applications installable by other means, usually over the internet via a distribution software archive. Upgrades consists of every once in a while updating the kernel and software layers, stabilizing everything, then releasing a new version of the distribution. Classic Ubuntu has done exactly this for many years and its continued success provides an important touchstone for moving forward.

While the Linux distribution model is tried and true and extremely flexible, using it in a modern application-centric world of interconnected devices and systems uncovers many challenges:

- Installed software is considered trusted by the Operating System (OS)
- The Operating System and applications are tightly coupled and applications must target a specific OS release, decreasing developer velocity
- Applications can change and have side-effects on the OS and vice versa

- Broken upgrades in one part of the system can prevent upgrades of the rest of the system

Before discussing the security features and design of Ubuntu Core, it is helpful first to explore the merits and challenges of the traditional Linux distribution (aka, distro) model, specifically classic Ubuntu.

Trust model: distro

One must first understand the underlying trust model when examining the security design of any OS. In classic Ubuntu (and other mainstream Linux distributions), software is typically distributed either:

1. as part of the installed system OS
2. via a trusted distribution archive
3. via opt-in installations or site-specific customized provisioning

Classic Ubuntu is split up into different flavors, eg Ubuntu Server, Ubuntu Desktop or Ubuntu Minimal. All of the different parts that make up an Ubuntu flavor are built using Debian-formatted packages ('debs') from the Ubuntu distribution archive. The Ubuntu archive itself is broken up into different 'components' which distinguish the level of support (official support from Canonical vs support from the Ubuntu community) and licensing constraints (Free Software vs freely distributable but otherwise non-Free software). The archive is further broken up into different 'pockets' that denote the nature of the update (eg, 'security' for security updates and 'updates' for non-security bug fixes). Archive integrity and OS upgrades contribute to classic Ubuntu's trust model.

Archive integrity

Ubuntu uses a "signed archive" and all uploads to the Ubuntu archive are restricted:

- Only verifiably signed source packages are allowed in the archive (all binary packages in the archive are built using source packages signed and uploaded by Ubuntu developers)
- Signed source packages are checksummed (all of MD5, SHA1, SHA256) and added to Ubuntu archive Sources file
- Binaries built from signed source packages are checksummed (all of MD5, SHA1, SHA256) and added to the Ubuntu archive's Packages file
- Sources and Packages files are checksummed (all of MD5, SHA1, SHA256) and added to Ubuntu archive Releases file
- Releases file is signed by Ubuntu archive gpg key and saved as Releases.gpg in the Ubuntu archive

Upgrades

Ubuntu upgrades may happen as part of applying security and high impact bug fixes to a stable release of Ubuntu or as part of upgrading Ubuntu from one release to another. Ubuntu releases a new version of the OS every 6 months with a Long Term Support (LTS) release usually every 2 years. LTS releases receive official support for 5 years and interim releases

receive official support for 9 months. Ubuntu Advantage customers may elect to purchase additional Extend Security Maintenance (ESM) updates to extend the support for select LTS packages beyond the official 5 year support. There is no distinction between OS upgrades, Ubuntu archive upgrades or 3rd party software upgrades during the upgrade process.

Ubuntu developers update software in the Ubuntu archive by updating a Debian source package (targeting a particular release), signing it with the GPG key associated with the developer's account in Launchpad[1], then uploading it to Launchpad where it is verified, built, automatically tested and published to the archive. This process is essentially the same regardless of whether the target release is for the development release or an existing stable release. The only differences are who is allowed to upload and the upload processes governing the target release. For example, only members of the Ubuntu Security team may upload to the 'security pocket'.

Software in classic Ubuntu: trusted by the OS

All of the above informs the trust model for classic Ubuntu, specifically, **software installed via the packaging system is considered trusted by the OS**. As such, Ubuntu's package manager, '`apt`':

- Is permitted to install its files on the system and perform administrative tasks as part of installation
- Can typically access any resources or data available within the user's session
- Has limited access to system services and data as defined by the OS (i.e., traditional filesystem permissions, PolicyKit, etc)
- May receive security and high impact bug fixes depending on the software's support status
- May optionally run under specialized confinement after installation

Challenges for distro model

The classic Ubuntu distribution is a time-tested, well-understood and very flexible model that is well-suited for many purposes, but it also has a number of drawbacks for the modern, fast-paced, app-centric world:

- The OS and installed software are viewed holistically by the system rather than separately. This can complicate testing, impede reproducibility, introduce unpredictable interactions between software, etc.
- In order to maintain stability and reliability of the whole system, Ubuntu archive stable release update policies dictate that the base versions of software found in a particular release of the distribution (typically) should not change. Instead, bug and security fixes must come from isolated source code patches to the stable release version rather than new upstream software releases.
- Because of Ubuntu's update policies, new features may (typically) only be introduced with new Ubuntu releases and not as part of the stable release update process. This

[1] Launchpad is the collaboration, project hosting and build service that Ubuntu uses

significantly decreases developer velocity since developers and users must wait up to 6 months before new features to the software can be added to the next OS release.
- All software installed using the system package management system, whether it comes from the trusted Ubuntu archive or not, is considered trusted by the OS. More concretely, installing packages gives the packager of the software full access to the system.

To answer some of the challenges inherent in Ubuntu's distribution model, classic Ubuntu employs many OS and toolchain hardening features to guard against attacks. Users are also advised to only install packages from the official Ubuntu archive or from trusted sources.

Staying up to date

As mentioned, classic Ubuntu uses the `apt` package management tool to perform individual package updates via a signed archive. The upgrade process consists of:

- When checking for updates, client systems download the Releases.gpg, Releases, Packages and optionally Sources files
- The Releases file is verified using Releases.gpg and the locally installed Ubuntu archive gpg public key
- If the Releases file verifies, the checksums for the Packages file are verified (and Sources if needed)
- If there are updates, the updated binaries are downloaded and their checksums verified against the contents of the Packages file (source packages are verified against the Sources file)
- After downloading all of the updated packages, the updates are installed

In order to maintain security, the system must always be kept up to date. The update system on Ubuntu may be configured in various ways, such as to apply updates automatically (e.g., via '`unattended-upgrades`' (the default for new installs as of 16.04 LTS), but this will never automatically trigger a reboot) or to prompt when a new version of Ubuntu is released.

While the venerable `apt` package management system has many admirable qualities, it lacks some important features such as transactional updates and rollbacks. For example, it is possible for a packaging bug in one package to prevent updates to the system or other unrelated packages even when '`unattended-upgrades`' is in use. When this happens, unapplying the broken update and fixing the system is a manual process. Site-specific update policies, APT-proxies, management tools (such as Canonical's enterprise management tool, Landscape), configuration management systems, etc are sometimes employed to mitigate these deficiencies.

Boot security

Classic Ubuntu employs a typical boot process:

1. The firmware/BIOS powers on, performs self-checks and passes control to a 1st stage bootloader. Depending on the architecture and target system, this bootloader may be

the standard Ubuntu bootloader (GRUB) or something that boots a second stage bootloader.
2. The bootloader (1st or 2nd stage depending on the target system) boots the kernel
3. The kernel loads its initrd (initial ramdisk) and any required kernel modules
4. The kernel starts the init process (ie, systemd on Ubuntu 15.04 and higher)
5. The init process launches console logins, system services, application services, etc

This traditional scheme requires that host security not allow any of the above steps to be subverted.

Classic Ubuntu also supports enforcing UEFI Secure Boot[2]:
1. The firmware/BIOS powers on, performs self-checks and verification of firmware modules, then verifies the bootloader. If the bootloader verifies, control is passed to it.
2. The bootloader verifies the kernel. If the kernel verifies, the kernel is booted with UEFI quirks enabled. Otherwise, the boot fails.
3. The kernel then verifies the modules required to boot. If a module fails to verify, it is blocked from loading and the failed verification is logged. In either case, the initrd is loaded.
4. The kernel starts the init process (systemd)
5. The init process launches console logins, system services, application services, etc

In this manner, a root of trust that is set in device firmware can be used to verify the system to the running kernel to protect against attacks on early boot, which is quite useful since the kernel enforces security policy on the system. To accommodate freedom and developer needs, the system supports DKMS and user key enrollment via MokManager as well as using a fallback mode via a firmware setting.

System, application and network security

The security of a classic Ubuntu system is a complex topic with many contributing factors:
- Ensuring the system is kept up to date with security fixes (Canonical provides timely updates for officially supported software)
- Ubuntu's use of many OS and toolchain hardening features[3]. Some of these include:
  - Kernel hardening such as 0-address protection, /dev/mem protection, /dev/kmem disabled, read-only data sections, compiled with stack protector, module RO/NX, kernel address display restriction and blacklisting rare protocols. Opt-in features include blocking module loading, syscall filtering (seccomp) and blocking kexec

---

[2] Planned for 18.04 LTS and 16.04 LTS via package upgrade. Ubuntu initially supported non-enforcing UEFI Secure Boot for enablement purposes where if the kernel failed to verify, ExitBootServices() would be called by the bootloader and then it would boot the unverified kernel.
[3] https://wiki.ubuntu.com/Security/Features

    - Userspace hardening such as symlink and hardlink restrictions, ptrace restrictions, /proc/<pid>/maps restrictions, and NX/XD support
    - Toolchain hardening by default (stack protector, heap protector, pointer obfuscation, ASLR (stack, libs/mmap, brk, VDSO), fortify source) with additional opt-in hardening (PIE[4]/exec ASLR, RELRO, BIND_NOW)
    - AppArmor Mandatory Access Control (MAC) confinement. AppArmor can mediate: system files and user data, networking, library loading, execution of applications, Linux kernel capabilities, mount, DBus, IPC (signals, ptrace, unix sockets, …), and can be used to confine containers at the container level[5] as well as applications within the container[6]
- Ubuntu's implementation defaults for officially supported software. These include:
    - Safe, usable default file permissions (including filesystem capabilities and limiting SUID binaries)
    - Logins disabled for well-known system accounts (eg, root, www-data, etc)
    - Open network ports in the default install are limited to network infrastructure services like dhcp client and avahi
    - Use of strong password hashing (SHA512crypt)
    - Usable but safe configuration defaults
    - Restrictive DBus bus policy for DBus system services and restrictive PolicyKit policies for interacting with privileged processes
    - Running services as non-root or privilege-separated whenever possible
    - Ensuring compiler hardening options are turned on for sensitive software or configuration hardening (eg, turn on seccomp sandbox in openssh, network namespace in vsftpd, etc)
    - Netfilter is available in the kernel and firewall software is installed by default on Ubuntu Server and Desktop (ufw, iptables)
    - AppArmor profiles enabled/available for select applications[7] (eg, virtual machines, LXC containers, software having a history of vulnerabilities or that is network facing, etc)
- Ensuring deb-based software is only installed from trusted sources
- Starting with Ubuntu 16.04, all flavors may install snaps from the Snap Store. On a traditional system, signature verification is performed on snaps installed from the Snap Store and these snaps are run within a restrictive sandbox[8] by default[9].

---

[4] PIE is by default on s390x in 16.04 LTS. In 16.10 and later, PIE is default for amd64, ppc64el and s390x.
[5] For example, both LXC/LXD and Docker utilize AppArmor to help protect the host from container guests
[6] LXD be default allows application policy in the container that is separate from host policy
[7] https://wiki.ubuntu.com/SecurityTeam/KnowledgeBase/AppArmorProfiles
[8] The classic Ubuntu Desktop system uses the X window system and snaps targeted to run in these environments therefore cannot be fully confined (see below)
[9] Certain approved snaps may run without restriction (so-called, 'classic confinement'). Classic confinement is not available on Ubuntu Core

- Proper user and password management. As part of the installation process, a user account is setup and it is automatically added to the ‘sudo’ group and is thus capable of running commands as root with password prompting.
- Appropriate non-default configuration by someone knowledgeable
- Ensuring 3rd party software is free from defects

Because the classic Ubuntu system is infinitely flexible and has tremendous utility (nearly anything can be built using it), there are a number of challenges to the overall security stance of a deployed system because the Ubuntu archive is a rich ecosystem with thousands of packages and the secure configuration and interaction between different software components relies on a combination of the upstream developer’s intent, Ubuntu packaging and the user/administrator’s use. For example, consider a system that is setup to provide a webserver to serve various web pages. The administrator installs Apache using ‘`apt-get`’. While Apache in Ubuntu is compiled with hardening (such as PIE) and supplies a reasonable default configuration, the administrator could accidentally configure the Apache web server to run as root and serve all of the system’s files, exposing sensitive information. After the configuration problem is fixed, the administrator could install a poorly written 3rd party PHP script which can be made to execute any programs on the system under the ‘`www-data`’ user. After that vulnerability is addressed, a separate vulnerability in an installed content management system (CMS) could then allow a similar attack. To guard against attacks and exposing sensitive information, an administrator might employ processes surrounding configuration management and/or write a site-specific AppArmor profile for Apache to help mitigate against flaws or misconfiguration of the system.

Complex interactions can also impact security, such as the intended PolicyKit permissions of NetworkManager being obviated by a separate installed DBus system service that didn’t implement its API correctly which might be subverted into proxying requests to NetworkManager without authentication. To thwart this, site-policies might dictate restrictions on installed software or the administrator might write a site-specific AppArmor profile, adjust the DBus bus policy and/or adjust PolicyKit configuration for the various services.

It is also possible that updating one part of the system could have a side-effect on another part of the system which could cause a component to crash or fail open. For example, an API call could have changed its internal default or a plugin is now required for implementing a security check that is no longer installed by default after performing an OS upgrade.

While classic Ubuntu is implemented to be secure by default and infinitely extendable and configurable, these examples illustrate some of the considerations when maintaining a strong security stance on a traditional Linux distribution like Ubuntu.

Logging

Classic Ubuntu systems use 'systemd' as the 'init' process by default and therefore all system logging information can be accessed via the 'journalctl' command. In addition, systemd is configured to forward all logging information to the 'rsyslog' logging service. The system uses a simplified logging scheme (which can be modified for site requirements) that consists of:

- **/var/log/auth.log**: all authentication logs ('auth.*' and 'authpriv.*')
- **/var/log/syslog**: everything except authentication logs ('auth.*' and 'authpriv.*'). AppArmor and seccomp denials are logged here.
- **/var/log/kern.log**: all kernel logs ('kern.*')
- **/var/log/mail.log**: all mail logs ('mail.*')
- **/var/log/audit/audit.log**: all kernel audit subsystem (including kernel LSM denials) when 'auditd' is installed[10]

'rsyslog' by default is not configured for remote logging (sending or receiving) and is configured to log some of the above into additional log files in /var/log. Applications may log to their own log files and the 'dmesg' command is also supported. Older versions of Ubuntu Desktop use 'upstart' as the session bus and it will log session services to files in '$HOME/.cache/upstart'.

Clock synchronization

By default, Ubuntu uses 'systemd-timesyncd' for time synchronization with remote NTP servers and it is enabled by default. 'chrony'[11] is also available and officially supported by Canonical.

Data encryption

Classic Ubuntu offers full disk encryption (dm-crypt of everything except the /boot partition) as part of the installation process.[12]

Trusted Platform Module

TPM is a standards-based embedded security subsystem typically implemented as a hardware chip on the mainboard. Classic Ubuntu has TPM 1.2 and 2.0 support enabled in the kernel (CONFIG_TCG_TPM and CONFIG_HW_RANDOM_TPM). TPM 1.2 userspace is provided by tpm-tools and TrouSerS and the TPM 2.0 userspace components consist of tpm2-tools and libtss2-0. TPM is not currently integrated into Ubuntu beyond the inclusion of these tools.

---

[10] 'auditd' is not installed by default but is officially supported by Canonical

[11] 'ntp' and 'ntpdate' are officially supported on older releases of Ubuntu

[12] Encrypted HOME (eCryptfs; encrypting each user's data with different encryption keys wrapped with the user's passphrase) is also available as part of the installation process on older releases of Ubuntu

Ubuntu Core

Ubuntu Core is in many ways simply another flavor of Ubuntu (eg, the root filesystem is built from packages from the same Ubuntu archive as other flavors), but it differs in many important ways:

- The base system is a minimal system[13] that consists of three different parts: the kernel, gadget and OS which are all packaged and delivered using the new snap packaging format
- There is a clean separation between the base system and the applications installed on the system as well as a clean separation between installed applications
- Ubuntu Core replaces '`apt`' with the new '`snap`' command and applications are packaged and delivered as 'snaps'
- The root filesystem is read-only
- Publishers may update applications independently of the OS
- Applications run in a security sandbox by default
- Ubuntu Core is application-centric instead of distribution archive-centric

The above qualities aim to address many of the challenges inherent in the traditional Linux distribution model and greatly increase reliability, predictability and security.

Trust model: snaps and the store

The trust model of Ubuntu Core is different from classic Ubuntu and this is due in part to how software is distributed. Software is either:

1. Part of the OS snap[14] (constructed from debs from the Ubuntu archive)
2. Pre-installed via the gadget snap (snaps installed during provisioning)
3. Installed via the store as application snaps or snap runtimes (base snaps)

Software on an Ubuntu Core system can then be categorized as:

- **Untrusted by the OS**
  To facilitate developer velocity and allow users to access the latest versions of applications without updating their OS, snaps are distributed via the Snap Store. Snap Store snaps are considered untrusted (more on this later) and run in a restricted sandbox. This allows store reviews of snaps to be shallow and automated as per store policies. Untrusted applications:
    - can freely access their own data
    - cannot access other applications' data
    - cannot access non-application-specific user data
    - cannot access privileged portions of the OS
    - cannot access privileged system APIs

---

[13] Not to be confused with Ubuntu Minimal, which is a stripped down classic Ubuntu flavor
[14] Newer versions of Ubuntu Core also have a 'snapd' snap that is separate from the OS snap. For the purposes of this discussion, snapd should simply be considered as part of the OS

    - may access sensitive APIs with user permission provided the API asks for permission at time of access or the permission is granted to the application outside of snap installation
- **Trusted by the OS**
  Software installed as part of the OS snap is considered trusted by the OS because it is built from the Ubuntu archive[15], therefore all the previously discussed archive integrity checks for classic Ubuntu also apply for the software shipped in the OS snap. This software may or may not run under confinement. Applications trusted by the OS:
    - can typically access any resources or data available within the user's session
    - have limited access to system services and data as permitted by the OS (ie, traditional file system permissions, Linux kernel capabilities, DBus bus policy, etc all apply)

Some snaps may implement interfaces (discussed in detail below) to mediate access to resources it shares and will have the necessary privileged access to the system to function. Store policies and security policies work together to ensure the system is secure.

Store policies

When the author of an application releases a new version, the snap package is uploaded to the Snap Store and the snap undergoes automatic reviews. Part of this review process involves examining the snap's requested interfaces (security policy, described below).

If a snap passes the review, it can be made immediately available to users and devices. If it does not pass review, it is blocked and the uploader may request a manual review. The store's upload policies and the security policies associated with an individual snap's declared interfaces work together to ensure that users and devices are protected from malformed or malicious snaps.

The official public Snap Store is intended for anyone and it therefore has very strict upload policies. OS, kernel, gadget and base snaps require manual review. Snaps implementing very sensitive Ubuntu Core interfaces must be pre-approved using store snap declaration assertions.

Brand stores (hosted via the Snap Store) are designed for individuals and companies to distribute software with various controls that are appropriate for the brand. Brand stores are essentially owned by a particular brand (ie, individual/company) and may optionally specify different upload policies as the brand sees fit. For example, it is possible to restrict uploads to certain employees in the brand's company. The company may also change their store upload policies or snap declaration assertions to allow app snaps implementing a sensitive security interface to pass automated review provided they come from the owner of the store. Access to brand stores can optionally be configured to be limited to either all devices owned by the brand, or specific models owned by the brand.

[15] Kernel and gadget snaps are either supplied by Canonical or the vendor

Staying up to date

Because the OS and installed applications are treated separately, their update processes differ.

System update process

In general, the base system is delivered via three snaps that work together:

- OS[16]: provided by Canonical
- Kernel: provided by either Canonical[17] or the vendor of a particular device
- Gadget: provided by either Canonical or the vendor of a particular device

The kernel snap provides the kernel and drivers, the OS snap provides the rest of the operating system and the gadget snap provides boot, kernel, OS and application configuration. Each of these snaps may be updated independently of one another.

For Canonical-provided OS and kernel snaps, since the snaps are based on debs from the Ubuntu archive, the update process relies upon the classic Ubuntu archive distribution model (though the delivery to devices is of course as 'snaps' instead of 'debs').

The OS and kernel snap update process has an additional step over classic Ubuntu: the channel[18] which can be thought of as 'risk level'. When an Ubuntu Core system is initially provisioned, it will contain a core snap (eg, core16, built from Ubuntu 16.04 LTS[19]) and a kernel snap. These snaps will target a particular channel (eg, 'stable'). Updates will flow from the Ubuntu archive to the Snap Store into the 'edge' channel for a given Ubuntu core and kernel snap automatically. Updates to the 'stable' channel may originate from other channels (eg, 'beta' or 'candidate') and undergo additional QA so that the stable channel is updated on a predictable cadence. High impact security updates or critical bug fixes may be pushed to the stable channel outside of this process and cadence as necessary.

For gadget and vendor kernel snaps, the origin of the snap is the publisher/vendor of the snap instead of the Ubuntu archive and updates to these snaps are done via direct upload to the Ubuntu (or brand) store. The store limits who can upload what via store accounts.

Ubuntu Core systems retain previous versions of snaps to support rollbacks and improve reliability[20]. For example, if on reboot after updating the kernel or OS snap the system fails to come up, it is rebooted to use the previous known-good kernel or OS snap.

---

[16] Including the aforementioned 'snapd' snap

[17] Canonical provides reference kernels based on officially supported kernels in the Ubuntu archive but Canonical can also work with vendors to provide vendor kernels via the Ubuntu/brand store

[18] See http://snapcraft.io/docs/reference/channels for the full list of channels and how they are used

[19] Unlike classic Ubuntu, Ubuntu Core snaps are not released on a 6 month cadence and therefore the version number corresponds only to the year of the release (typically corresponding to the year of classic Ubuntu's Long Term Support release)

[20] Ubuntu Core 15.04 used system images with an a/b partitioning scheme instead of snaps to support rollbacks

Ubuntu developers who want to update the OS or reference kernel snap will:

- Update a Debian source package (targeting a particular classic Ubuntu release), sign it with the GPG key associated with the developer's account in Launchpad, then upload to Launchpad where it is verified, built, automatically tested and published to the archive

Canonical's automated processes will, per Ubuntu release and channel:

- Via '`apt`', notice that packages in the Ubuntu archive are newer than what is in the current snap for this release/channel
- Rebuild the snaps using the contents of the newer versions of the debs
- Publish the snap (and its associated deltas) as per the channel policies
- Calculate snap deltas as per Snap Store policies

Ubuntu Core systems will:

- Via https, notice that an update is available
- Via https, calculate whether to use snap deltas or the full snap
- Via https, download the updated snap or snap deltas
- Verify the signature of the snap/applied snap deltas with the server's public key
- Update the boot configuration to use the new OS and/or kernel snap

Ubuntu Core systems are configured by default to automatically install updates and reboot[21] to improve security. The '`snap refresh <snap name>`' command may also be used at any time to trigger an update, prompting to reboot. The store also provides a gating mechanism for publishers to coordinate updates of multiple snaps own by the publisher.

App, gadget and vendor kernel update process

The update process for application, base, gadget and vendor kernel snaps is different than the system update process because publishers simply upload directly to the store. The publisher will:

- Develop the snap (and for app snaps, bundling any necessary libraries, data and programs to properly run)
- Create an account on Launchpad (if not done already)
- Create a project for this snap (one time only) in the Snap Store tied to the Launchpad account
- Optionally sign the snap with the developer signature[22]
- Upload the snap to the store under the appropriate Launchpad account and store project via https, targeting particular channels[23] and whether or not to automatically publish to a channel if the snap passes review

---

[21] The timing of updates can be influenced via OS snap configuration or Brand Store controls

[22] The snap publisher may optionally configure the store to verify the uploaded snap against a developer signature

[23] The publisher may also request the use of store 'tracks' which can, for example, be used to group different upstream releases and channels (eg, an 'lts' track and a 'current' track, each with their own stable, candidate, beta and edge channels)

The store will then:

- Perform automated checks on the uploaded snap. If errors are found, they are reported to the uploader and the snap is not published
- If the snap passes automated checks, the store GPG-signs the snap with a store signing key and publishes the snap to the store either automatically or when the uploader triggers it at a later time

Ubuntu Core systems will:

- As part of the factory install process[24], a unique identifier for the device (eg, a serial number) will be signed by the vendor. The vendor's public key will be given to Canonical and optionally associated with a Brand store for the vendor
- On first launch, the device will register with the store by presenting the signed unique identifier to the store and optionally which Brand store to access. The store will verify the signature and if specified, register the device to the Brand store. A device may only be registered with one store
- Query the public Snap Store or a Brand store via https for any updates
- If updates are available, download the updated snaps via https
- Verify the signature of the snap with the store's public key
- If verification succeeds, install the snap

Like with OS and kernel snaps, Ubuntu Core systems are configured by default to automatically install updates for applications and all other snap types. The '`snap refresh <snap name>`' command may also be used at any time to trigger an update. Package rollbacks are supported via the '`snap revert <snap name>`' command.

Boot security

Ubuntu Core has the same boot process as classic Ubuntu and supports both traditional boot and enforcing UEFI Secure Boot for amd64 (see above). Unlike classic Ubuntu, snaps on Ubuntu Core run under an application sandbox and malicious applications or subverted processes are not allowed to modify the firmware, bootloader, kernel, modules, initrd, and init and they are not allowed to interact with the base system except in very controlled ways.

System security

System services

The Ubuntu Core base system (ie, the kernel and OS snap) contains little more than a kernel, the init process, snapd itself, standard Linux/UNIX tools, libraries to support these tools and a few standard tools to make application development easier. Therefore, it offers a reduced attack surface comprised of:

- Kernel syscall interface, modules as well as /proc and /sys entries
- If configured, a listening dhclient (DHCP client). The dhclient program runs under a restrictive AppArmor profile by default.

[24] This describes the store interactions for Ubuntu Core devices. The old Ubuntu Core 15.04 factory process differed substantially

- OpenSSH listens by default[25] and is configured with '`PermitRootLogin prohibit-password`' to disable root logins when a password is set. '/etc/ssh/sshd_config' is writable, so it can be updated for site-specific needs.
- A few other non-network-facing services exist to support normal system operation. Eg, init (systemd), systemd-journald, systemd-networkd, systemd-udevd, systemd-timesyncd, systemd-logind, systemd-resolved, dbus-daemon, snapd, etc[26].
- Because the base system is built from the Ubuntu archive, it benefits from all of the OS and toolchain hardening features of classic Ubuntu.

App snaps by default are disallowed access to all system services and have limited access to kernel interfaces. Ubuntu Core also provides restricted interfaces that the gadget developer or device administrator may assign (connect) to trusted snaps.

Users

The administrative user (ie, 'root') has a disabled password. All system users have disabled logins.

As part of provisioning, one user account is setup using the Launchpad ID as the name of the user. By default this user has console access disabled and SSH access allowed via the ssh key stored in Launchpad for the user. This user is in the 'sudo' group and is thus capable of running commands as root (by default without password prompting but configurable via '/etc/sudoers.d/create-user-<username>'). Console access may be allowed by setting a password for the user.

Multiuser support is limited on Ubuntu Core, but alternate user accounts can be set up using standard tools (eg, '`addgroup`', '`adduser`', etc).

Per-snap users are planned for Ubuntu Core and will be implemented at a future date.

App services and user commands

The Ubuntu Core system is designed to segregate the system from applications, and to segregate applications from each other, while providing controlled mechanisms for interacting with each other. For example, snaps are not allowed to use `crond`, change to another user, have unapproved access to hardware, add `rsyslog` rules, add users, ship setuid/setgid programs, change security policy, modify the system, modify kernel runtime variables, access sensitive kernel syscalls, etc.

Snaps provide commands that may or may not run in the background. Commands that the user runs via console logins are installed in `/snap/bin`, which is included in the console user's PATH. Services are commands that run in the background and are long running processes that

---

[25] OpenSSH can be disabled via the gadget snap or `` `snap set core service.ssh.disable=true` ``

[26] Different Ubuntu Core releases may differ slightly (eg, Ubuntu Core 16 has cron and cgmanager but doesn't have systemd-resolved)

integrate with the systemd boot process to start automatically on boot. While the systemd unit specification is very rich, Ubuntu Core only exposes a very small subset of the specification in the snap packaging: start-command, stop-command, post-stop-command, stop-timeout, daemon type, etc. On system install, the systemd unit file is autogenerated based on these packaging options. This prevents snaps from interacting with systemd and the system in uncontrolled ways.

Certain Ubuntu Core interfaces provide DBus bus policy and security policy allowing running as a DBus service. While the DBus bus policy specification is also rich, the OS snap itself provides the bus policy instead of the snaps implementing the interface.

Importantly, to prevent unexpected interactions and maintain co-installability, whenever the system and snaps could potentially collide, the system will use naming conventions to avoid a collision. For example, snaps are installed to a snap-specific path, DBus connection names and interfaces are provided by the OS snap, socket activation and connections must follow snap-specific naming schemes, etc (discussed in detail, below).

Application security

Application security is achieved through the combination of security and store policies working together.

Application developers typically do not have to understand the low level implementation details on how security policies are enforced. Instead, security policy is declared through an easy-to-use interfaces system. Ubuntu Core also provides a per-snap developer mode to ease application development and working with the sandbox.

Gadget developers typically do not have to understand the low level implementation details of confinement, but they may want to preconfigure snaps' interface connections to work with the gadget's hardware.

In order to better understand how confinement works, it is helpful to be familiar with several concepts:

- App snaps
- Gadget snaps
- Security policy ID
- Application launching
- Ubuntu Core FHS (Filesystem Hierarchy Standard)
- Security trust model (previously discussed)
- Store policies (previously discussed)
- Ubuntu Core security primitives
- Snap security policy

App snaps

App snaps are the primary method for making an Ubuntu Core system useful. App snaps are used to ship services that should start on boot or commands that the user or admin can run. All app snaps run under confinement in a restrictive security sandbox that is configured in the snap packaging.

Because the Ubuntu Core base system is minimal, snaps bundle everything they need in the snap which allows developers to carefully control the application's runtime environment. This technique adds predictability and reliability to the development process, but it also means that publishers are responsible for security issues found in the bundled parts. The snapcraft tool can help because it allows developers to bundle debs from the Ubuntu archive in snaps. Snapcraft also makes it easy to rebuild those snaps with updated debs that have received a security fix since publishers can opt into receiving notifications for Ubuntu archive software that has received a security update since the snap was last published.

Gadget snaps

Gadget snaps may be used to declare hardware capabilities to the system and pre-assign access to snaps that need to use this hardware.

Security policy ID

Applications are tracked by the system using the concept of a security policy ID and this ID is the composition of elements from the snap's packaging. Specifically, it consists of the package name and the command name. The security policy ID takes the form of **snap.<name>.<command>**[27].

For example, if this is in the snap packaging:

```
name: foo
...
apps:
  bar:
    command: bin/bar
```

then the security policy ID for the '`bar`' command is '**`snap.foo.bar`**'. The security policy ID is used throughout the system including in the enforcement of security policy by the application launcher.

[27] Recent versions of snapd also support 'parallel installs' where different revisions of the snap can be co-installed. In this instance, the security policy ID is **snap.<name>_<parallel instance>.<command>**

Application launch

Whether the snap contains services or user commands in its snap packaging, launching of these executables happens via the 'snap run' command and 'snap-confine' (aka, the launcher) and the security policy and 'snap-confine' enforce application isolation. The commands in '`/snap/bin`' are symlinks to '`/usr/bin/snap`' and the systemd unit files use '`Exec=/usr/bin/snap run`' such that when an application is started:

- 'snap run' will determine the command to launch using the name of the symlink
- 'snap run' will set up various environment variables (see below)
- 'snap run' will call 'snap-confine'
- 'snap-confine' will change directory to a writable data directory (see below. Note, for background services it is the systemd service definition that specifies the working directory)
- If hardware access is assigned to the snap, 'snap-confine' will set up a device control group with default devices (eg, `/dev/null`, `/dev/urandom`, etc) and any devices which are assigned to this snap (more on this later)
- 'snap-confine' will set up the seccomp filter. Seccomp is a Linux kernel syscall filter (see below). All child processes inherit the parent's filter.
- 'snap-confine' will set up a devpts new instance for the command (see below)
- 'snap-confine' will set up a private /tmp for the command and apply any additional mounts into the snap's runtime as defined by interface connections
- 'snap-confine' will set a default nice value
- 'snap-confine' will execute the command under an AppArmor profile. AppArmor is a Linux Security Module (LSM) that implements Mandatory Access Controls (MAC, see below). Child processes inherit the parent's policy unless the policy defines a profile transition.

Importantly, the snap's security policy does not allow modification of the security sandbox in which it runs (this is reserved for the launcher, which snaps do not control). Because the launcher needs privileges to set up the sandbox, the launcher itself is confined with a restrictive AppArmor profile.

This combination of technologies and restrictive security policies provide for strong application confinement and isolation.

Ubuntu Core FHS (filesystem hierarchy standard)

Each Ubuntu Core system adheres to the Ubuntu Core filesystem layout so that snaps are separate from the system and each other. In terms of application confinement this simply means there are areas of the filesystem that are designated as **read-only** and areas that are designated as **writable** by the snap. On application start several environment variables are set to help applications determine their readable and writable areas, origin, version, etc. These variables are:

- `SNAP`: installation directory (**read-only)**
- `SNAP_ARCH`: architecture of the system (eg, amd64, arm64, armhf, i386, etc)
- `SNAP_DATA`: per-revision application data directory (**writable**)
- `SNAP_COMMON`: application data directory common to all revisions (**writable**)
- `SNAP_LIBRARY_PATH`: library paths added to LD_LIBRARY_PATH
- `SNAP_NAME`: package name
- `SNAP_INSTANCE_NAME`: package name plus parallel install instance name
- `SNAP_INSTANCE_KEY`: parallel install instance name
- `SNAP_REVISION`: store revision for this snap
- `SNAP_USER_DATA`: per-revision, per-user application data directory (**writable**)
- `SNAP_USER_COMMON`: per-user application data directory common to all revisions (**writable**)
- `SNAP_VERSION`: package version
- `TMPDIR`: temporary directory (**writable**)
- `HOME`: set to SNAP_DATA for services and SNAP_USER_DATA for user commands. The working directory for commands is changed to this on launch
- `XDG_RUNTIME_DIR`: set to /run/user/<uid>/snap.$SNAP_NAME (**writable**)

Ubuntu Core security primitives overview

Several technologies are used by Ubuntu Core to implement the security sandbox. The security sandbox is designed so that snaps are integrated into the OS and can interact with one another in controlled ways.

Traditional permissions

The Linux kernel enforces Discretionary Access Controls (DAC) via traditional UNIX 'owner' permissions as well as Linux kernel capabilities and the Ubuntu Core base system uses these permissions extensively. For app snaps on Ubuntu Core, services run as root and therefore traditional permissions alone do not play as important of a role in the confinement of services. Future versions of Ubuntu Core will allow snaps to optionally request snap-specific, non-root users and groups for services.

AppArmor

AppArmor is a Mandatory Access Control (MAC) system which ensures kernel level enforcement of programs and processes to a limited set of resources. AppArmor restricts processes running either as root or non-root and confinement policy is provided via profiles loaded into the kernel. AppArmor in Ubuntu Core mediates:

- File access and library loading
- Execution of applications
- Coarse-grained networking
- Linux kernel capabilities
- Coarse owner checks (euid/fsuid matching)

- Mount
- UNIX named, abstract and anonymous sockets
- DBus communications
- UNIX signals
- Process tracing (ptrace)

An important concept to understand is when a process is started an AppArmor label is attached to it. This label is used to map the process to its policy and is consulted in process interactions and file accesses. The label for a snap's process is the same as its security policy ID (this is performed by the launcher). In this manner, all commands from a snap are given a unique label and all mediation is performed against the AppArmor policy associated with that label. When a process executes another binary, an execution transition is performed (if the policy allows it). AppArmor supports several different execution transitions, but the most important one to remember for typical application confinement in Ubuntu Core is that the child process will inherit the parent's label (and therefore policy).

Seccomp

When user space programs need to interact with the hardware (eg, to open a file or to connect to a machine over the network) or other kernel functionality, they do so via the syscall interface to the Linux kernel. The kernel has a few hundred syscalls for a given architecture and a process may set up a syscall filter using the seccomp facility in the Linux kernel to limit the syscalls the process may use. Child processes inherit the parent's seccomp filter and while they can make the filter more strict, they may not make it less strict. The launcher will set a seccomp filter for the command before executing it.

Namespaces

Namespaces are a facility provided by the Linux kernel that allows separating processes in such a manner that they cannot see or access resources from another namespace. Several namespaces exist, such as file, network, and mount namespaces. Namespaces play a vital role in container technologies such as LXC/LXD and Docker, but their use is not limited to these full-blown container implementations. Ubuntu Core uses a mount namespace to implement a per-snap `` `/tmp` `` directory and other features such as sharing content between snaps and the system.

In general, snaps' processes run in the global (ie, default) namespace to facilitate communications and sharing between snaps and because this is more familiar for developers and administrators. For those desiring full containers, LXD and Docker[28] snaps are available for installation from the store.

[28] The LXD and docker snaps necessarily have privileged access to the system and are fully functional on Ubuntu Core, therefore users should follow those projects' security guidelines to maintain security on the system.

Control Groups (cgroups)

Cgroups are a way to group processes for resource limiting, prioritizing, accounting, etc. Several cgroups exist, such as devices, memory, cpuacct, cpuset, net_cls and net_prio and cgroups are widely used in conjunction with container technologies. Ubuntu Core currently uses the devices cgroup for hardware device access controls for hardware assignment.

devpts newinstance

The Linux kernel provides pseudoterminal (PTYs) functionality for login sessions and TTY capabilities and supports System V/Unix98 naming schemes via the /dev/ptmx master PTY device file with slave PTYs in the /dev/pts filesystem. Ubuntu Core configures the devpts filesystem in multi-instance mode and mounts a new devpts instance per command to prevent snooping and input injection via `/dev/pts`.

Ubuntu hardening

Ubuntu hardening plays an important role in application security:

- YAMA LSM is enabled in Canonical-supported kernels and provides ptrace scoping, symlink restrictions and hardlink restrictions
- Canonical-supplied kernels have the kernel hardening benefits of classic Ubuntu kernels
- Applications using the Ubuntu Core base system libraries and interpreters as well as applications built with the Ubuntu toolchain and/or bundling debs from the Ubuntu archive (eg, using snapcraft) benefit from the same toolchain and glibc hardening protections available to classic Ubuntu and the Ubuntu Core base system

Snap security policy

Security profiles for snaps use a default security profile provided by the OS snap and are extended via Ubuntu Core interfaces. A snap’s packaging may declare requested interfaces to consume via plugs and requested interfaces to provide via slots (if unspecified, the default policy is used with no additional interfaces). Upon snap install, snap-specific security policy is autogenerated with any auto-connectable interface security policy. Interfaces that provide privileged access to the system are not auto-connected by default and the administrator of the system must manually connect these via the ‘`snap connect`’ command (the gadget developer may auto-connect preinstalled snaps via the ‘`prepare-device`’ hook).

When a snap is uploaded to the store, part of the review process involves examining the snap’s declared interfaces to determine if the snap meets the store’s upload policies. Certain interface declarations will trigger a manual review in the public Snap Store although the store may also grant snap declaration assertions for the snap that enables the snap to pass automated review. Brand stores may also issue snap declarations for snaps they control. As part of the install of a snap, the installation process will download any snap assertions and

consider them for snap interface connections. For example, snap declarations may be used to allow a specific snap to use a sensitive interface or to specify that an interface may be auto-connected for a particular snap.

When this section refers to 'snap packaging' for defining security policy for snaps, it applies to both '`meta/snap.yaml`' and '`snapcraft.yaml`'[29].

Default policy

The default security policy defines the bulk of the security policy. The default policy on Ubuntu Core enforces adherence to the Ubuntu Core FHS with enough access to the base system for the program to run. Specifically:

- read-only access to SNAP, which is set to the versioned install path
- write access to SNAP_DATA which is set to a versioned path in /var
- write access to SNAP_USER_DATA when the owner of the process and the owner of the file matches. SNAP_USER_DATA is set to a versioned path in /home
- write access to SNAP_COMMON which is set to a snap-specific path in /var
- write access to SNAP_USER_COMMON when the owner of the process and the owner of the file matches. SNAP_USER_COMMON is set to a snap-specific path in /home
- write access to XDG_RUNTIME_DIR which is set to a snap-specific path in /run/user/<uid>
- read-only access to install path and data directories of previous versions
- access to system libraries and a subset of executables in /bin, /sbin, /usr/bin and /usr/sbin
- write access to shared memory files (ie, /dev/shm/snap.SNAP_NAME.*)
- allow processes from the same snap to communicate with each other via abstract and anonymous sockets
- allow processes from the same snap to signal each other via signals
- various common accesses that are deemed safe

All commands within a snap share the same readable and writable areas and share the same mount namespace (/tmp). Importantly, the security policy dictates that files in SNAP_USER_DATA and SNAP_USER_COMMON[30] must be owned by the uid of the process accessing the files which means that a snap's daemons and commands running under sudo will not be able to access files in the non-root users' home directories (eg, under /home). In practice, this means that snaps need to consult HOME, SNAP_USER_DATA and SNAP_USER_COMMON for their per-user files and that shared files should be stored in SNAP_DATA or SNAP_COMMON under a directory with permissions appropriate for file sharing (eg, a directory with the sticky bit permission set).

---

[29] The details of working with Ubuntu Core security policy are discussed in depth in the online documentation

[30] This restriction also typically applies when using the 'home' interface

Devmode

To ease application development, Ubuntu Core supports installing applications in 'devmode' which installs the application in such a way that policy is not enforced, but policy violations are logged. This is often helpful for developers when first making a snap. For example:

```
$ sudo snap install hello-world --devmode
```

The packaging yaml also supports the '`confinement`' directive to specify whether or not the snap is expected to work correctly when the specified interfaces are connected and the snap is confined. Specifying '`strict`' in the packaging yaml indicates the snap works properly when confined and '`devmode`' indicates it only works properly when unconfined. If '`confinement`' is unspecified, the snap is assumed to work correctly when confined since developers are expected to develop their snaps for running in the sandbox. Uploads targeting the 'stable' channel in the store may not specify '`confinement: devmode`' in the packaging yaml. Importantly, specifying '`--devmode`' is always required when installing a snap in devmode regardless of how '`confinement`' is set in its packaging yaml.

Classic

The installation process also supports installing applications that specify '`confinement: classic`' which disables all security mechanisms in the snap and allows it to run completely unconfined. This directive can useful for some types of low-level tools or when first developing snaps as a step towards devmode. Use of '`confinement: classic`' is restricted by the store and snaps specifying this directive are not installable on Ubuntu Core[31].

Interfaces

Ubuntu Core implements many interfaces for snaps to request and use. The list of interfaces will grow throughout the lifetime of Ubuntu Core[32] and at any given time the list of available interfaces on a particular device (and the connection status) can be seen with '`snap interfaces`'. An important concept with interfaces is the connection: the OS snap or a snap service command implements a slot interface and a client may plug into (use) the slot when an Ubuntu Core interface connection is made. Interfaces form a contract between the slot provider and the plug consumer such that any snaps using a given interface will be able to interoperate with each other.

Ubuntu Core interfaces

The number of interfaces for Ubuntu Core is large and only a few representative interfaces are listed here to demonstrate what interfaces can do:

---

[31] Classic snaps may only be used on traditional distributions like Ubuntu Server and Desktop

[32] See [the snapcraft forum] for the most up to date list

- **firewall-control**: Can configure the firewall via netfilter and sysctl and grants the CAP_NET_ADMIN capability. Because this interface grants privileged access, this interface is not auto-connected on install and store policies may trigger a manual review for uploads of snaps specifying this interface.
- **home:** Can access non-hidden files in user's $HOME. Because this interface grants privileged access, this interface is not auto-connected on install and store policies may trigger a manual review.
- **log-observe**: Can read system logs from '`journald`', /var/log and also adjust kernel printk rate limiting. Because this interface grants privileged access, this interface is not auto-connected on install and store policies may trigger a manual review for uploads of snaps specifying this interface.
- **network**: Can access the network as a client
- **network-bind**: Can access the network as a server
- **network-control**: Can configure networking and network namespaces via sysctl, administrative commands (eg, ifconfig, route, ip, arp, etc) and grants the CAP_NET_ADMIN capability. Because this interface grants privileged access, this interface is not auto-connected on install and store policies may trigger a manual review.
- **network-observe**: Can query network status information via sysctl, administrative commands (eg, route, netstat, etc). Because this interface grants privileged access, this interface is not auto-connected on install and store policies may trigger a manual review for uploads of snaps specifying this interface.
- **snapd-control**: Can communicate with snapd over a UNIX socket to issue commands equivalent to those available through the snap command line tool. Because this interface grants privileged access, this interface is not auto-connected on install and store policies may trigger a manual review for uploads of snaps specifying this interface.
- **system-observe**: Can query system status information via /proc and the ps command. Because this interface grants privileged access, this interface is not auto-connected on install and store policies may trigger a manual review for uploads of snaps specifying this interface.
- **time-control**: Can set system time. Because this interface grants privileged access, this interface is not auto-connected on install and store policies may trigger a manual review for uploads of snaps specifying this interface.

Ubuntu Classic interfaces

Starting with Ubuntu 16.04, all Ubuntu flavors may install snaps from the Snap Store. This includes classic Ubuntu Desktop systems which use the X window system. On classic distributions, miscellaneous interfaces are provided for the various traditional desktop accesses required for a desktop application to run. Several of these interfaces do not provide full isolation of graphical applications running within the a specific user's session (eg, mediation for keyboard, mouse, screen grabs, clipboard, Xsettings, etc is not supported). Snaps of graphical applications using X should therefore only be installed from trusted

publishers[33]. Future releases of Ubuntu Desktop will use a display server which implements the Wayland protocol which is designed to address the security shortcomings of X.

Some interfaces are available only on classic Ubuntu systems (ie, not on Ubuntu Core). Some representative interfaces are:

- **desktop**: Can use modern DBus APIs and resources required to run under modern desktop environments as a client. This interface is safe to use and is auto-connected.
- **desktop-legacy**: Can use historic DBus APIs and resources required to run under various historic desktop environment as a client. This interface grants privileged access to the user's session via DBus APIs. This interface is auto-connected.
- **gsettings**[34]: Can use the user session's global gsettings database. This interface grants privileged access to the user's settings and is auto-connected.
- **opengl**: Can use OpenGL hardware and libraries. This interface is auto-connected.
- **wayland**: Can access a display server implementing the Wayland protocol. This interface is safe to use and is auto-connected.
- **x11**: Can use X as a client. This interface grants privileged access to the user's session via the shared X server. This interface is auto-connected.

Snap interfaces

In addition to these Core and Classic system interfaces, other interfaces exist on Ubuntu Core to facilitate snaps connecting to each other. For example, a snap providing a DBus service would declare it provides a slot interface for other snaps to use via their plugs declaration. The OS snap ships the interfaces and associated security policies for both the slot side (server) and the plug side (client), and the server snap implements the service within the added slot side security policy. Some representative additional interfaces available when a snap implementing the interface is installed are:

- **bluez**: Slot policy allows access for the bluez bluetooth service and provides DBus bus policy. Plug policy allows access to the services implementing the corresponding slot. Both sides require privileged access and the plugs side is not auto-connected on install. Store policies may trigger a manual review for uploads of snaps specifying this interface.
- **mir**: Slot policy allows access for the Mir display server. Plug policy allows access to the services implementing the corresponding slot. Slot side provides privileged access and store policies may trigger a manual review for uploads of snaps specifying this slot interface. The plug side will be auto-connected.
- **network-manager**: Slot policy allows access for the NetworkManager service to configure networking on the device and provides DBus bus policy. Plug policy allows access to the services implementing the corresponding slot. Both sides require privileged access and the plugs side is not auto-connected on install. Store policies may trigger a manual review for uploads of snaps specifying this interface.

[33] This only applies to classic Ubuntu flavors using X. Ubuntu Core is not affected.

[34] Safe snap-specific access to gsettings is planned. When implemented, most applications that use gsettings will not require this privileged global gsettings interface.

- **pulseaudio**: Slot policy allows access for the pulseaudio service to playback and record [35] audio. Plug policy allows access to the services implementing the corresponding slot. Slot side provides privileged access and store policies may trigger a manual review for uploads of snaps specifying this slot interface. The plug side will be auto-connected[36].
- **docker**: Slot policy allows access for docker to manage containers. Plug policy allows access to the service implementing the corresponding slot via the docker admin socket. Both sides require privileged access and the plugs side is not auto-connected on install. Store policies may trigger a manual review for uploads of snaps specifying this interface.
- **lxd**: Slot policy allows access for LXD to manage containers. Plug policy allows access to the service implementing the corresponding slot via the LXD admin socket. Both sides require privileged access and the plugs side is not auto-connected on install. Store policies may trigger a manual review for uploads of snaps specifying this interface.
- **location-observe**: Slot policy allows access for the location service to use the GPS. Plug policy allows access to the services implementing the slot. Both sides require privileged access and the plugs side is not auto-connected on install. Store policies may trigger a manual review for uploads of snaps specifying this interface.
- **dbus**: Slot policy allows access for binding to a well-known DBus name on the session or system bus. Plug policy allows access to the services implementing the slot. The slot side requires a snap declaration assertion from the store to grant use of the well-known name. Plug side is manually connected.

Interfaces in practice

To illustrate the concept of slots and plugs, consider a bluez5 snap that implements the bluez slot via its `bluetoothd` command:

```
name: bluez5
...
apps:
  bluetoothd:
    command: bin/...
    slots: [bluez]
    plugs: [network]
```

When the bluez5 snap is installed, the security policy ID for `bluetoothd` will be '`snap.bluez5.bluetoothd`' and it will have the default security policy plus '`network`' policy (since it is auto-connected) and the slot security policy needed for '`bluetoothd`' to run. A snap that wants to connect to `bluetoothd` from bluez5 would use:

---

[35] Separate audio-playback and audio-record interfaces is planned
[36] When audio-playback and audio-record are implemented, pulseaudio will no longer be auto-connected

```
name: bluez-client
...
apps:
  cmd:
    command: bin/...
    plugs: [bluez]
```

When the bluez-client snap is installed, the security policy ID for '`cmd`' will be '`snap.bluez-client.cmd`' and it will get the default policy only (since the bluez interface is not auto-connected upon install). Using the '`snap connect`' command (e.g. '`snap connect bluez-client:bluez bluez5:bluez`') the administrator would connect '`cmd`' to '`bluez5.bluetoothd`' and security policy would be regenerated to allow '`cmd`' to communicate with '`bluez5.bluetoothd`'.

Interfaces may either be declared per-command or per-snap. If declared per-snap (i.e. plugs and/or slots are declared in the top-level packaging yaml), all the commands within the snap have the interface security policy added to the command's security policy when the interface is connected. If declared per-command (i.e. plugs and/or slots are declared in the command's section of the packaging yaml, as in the above examples), only the commands within the snap that declare use of the interface have the interface security policy added to them. As a result, the '`snap connect`' and '`snap disconnect`' commands need only the snap name and not the command name.

The gadget snap may configure auto-connections for the device to avoid the '`snap connect`' command for pre-approved interface connections.

Snap packaging example

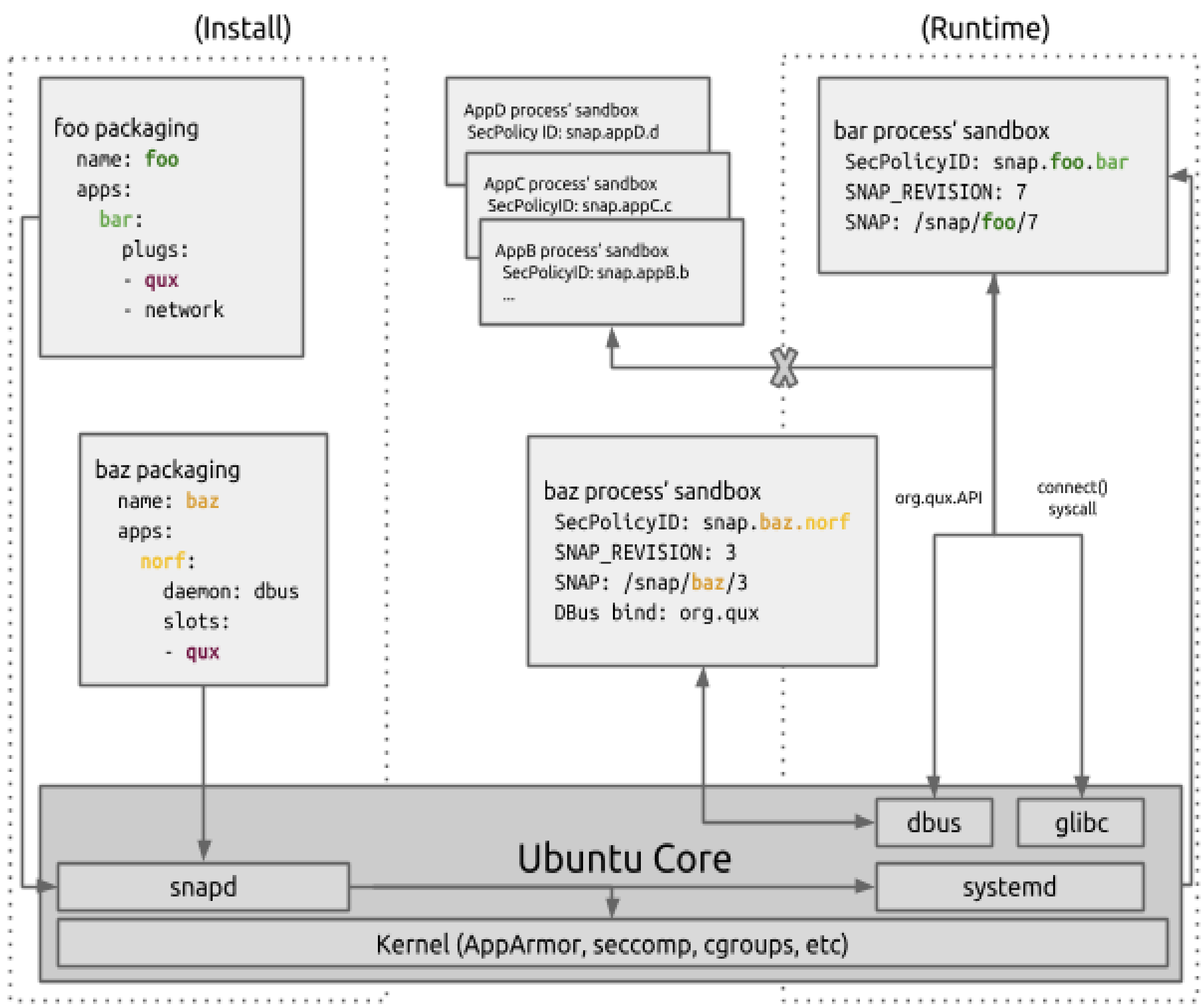
To understand how the snap packaging, security policy and runtime all work together, it is helpful to look at a full example. Consider the following is uploaded to the store and the snap is assigned revision 7 by the store:

```
name: foo
version: 1.0
description: foo does stuff
apps:
  bar:
    command: bin/bar-service
    daemon: simple
    plugs:
    - qux
    - network
  ctl:
    command: bin/control
```

With the above, the:

- Security policy ID for 'bar' is `snap.foo.bar`. It has the default security policy with the '`network`' interface auto-connected.
- Security policy ID for 'ctl' is `snap.foo.ctl`. It has the default security policy only.

For both of the above commands, the runtime environment variables are set to `SNAP_REVISION=7`, `SNAP=/snap/foo/7`, `SNAP_DATA=/var/snap/foo/7`, and `SNAP_USER_DATA=$HOME/snap/foo/7`. Note that the store revision is used in the snap-specific directories instead of the version number declared in the snap packaging. How snap packaging, interfaces and the runtime sandbox work together can be seen in the following diagram:



The '`foo`' snap plugs into the '`qux`' interface and '`baz`'s '`norf`' service implements the '`qux`' slot. After connecting the snaps with '`snap connect foo:qux baz:qux`', the security policies are

configured to allow (by seccomp filter) ‘`bar`’ to `connect()` to ‘`norf`’s DBus service at `org.qux` (by AppArmor policy).

Access to hardware devices

By default, snaps have very limited access to hardware devices, since unrestricted access to hardware could result in subverting security policy – for instance, a command with write access to the hard disk could alter security policy or a command with read access to `/dev/input/*` could log keystrokes. Ubuntu Core provides interfaces for assigning hardware to snaps that, like other interfaces, can either be manually connected or auto-connected via gadget snap assignment.

When working with hardware assignments, it is helpful to understand the relationship between udev and the interface connection. When hardware is assigned to a snap, a udev rule is added to ‘`/etc/udev/rules.d/70-snap.<name>.<command>.rules`’ and the rule tags that device as assigned by Ubuntu Core to the specified snap command. When the command is launched, the launcher will first query the udev database for any devices that have been tagged for this command and add those devices to the command’s devices cgroup.

Network security

Ubuntu Core reference images employ the following:

- OpenSSH enabled by default and configured with secure defaults (eg, sshd_config configured with ‘prohibit-password’). Can be disabled via `` `snap set` `` or the gadget snap
- Logins disabled for well-known system accounts (eg, root, www-data, etc)
- Logins disabled for the provisioned user by default
- No other open network ports (unless DHCP is enabled)
- Netfilter is available in the kernel and iptables in the OS snap
- ufw, the default firewall for classic Ubuntu installs, is also available in the store and can be installed with ‘`sudo snap install ufw`’. It provides bastion host firewall configuration for the admin user. Instructions on how to use it can be seen with the ‘`ufw.doc`’ command.

Certain provisioning options and gadget snaps that configure the OS snap and/or install additional snaps may open additional ports. If the device is provisioned with other snaps, other ports may or may not be open depending on the functionality of the snap. For example, installing ‘go-example-webserver’ will open 8081/tcp but installing the network-manager snap will not open any ports.

Furthermore, by default snaps:

- Do not run with CAP_NET_ADMIN
- Are not allowed to manipulate network interfaces, routing, QoS, network namespaces, etc
- Are not allowed to manipulate the firewall

- Are not allowed to monitor the network

Snaps may request '`network-control`', '`firewall-control`' or '`network-observe`' in their plugs to perform the above (subject to store upload policies).

Ubuntu Core does not provide advanced firewall configuration as part of the OS itself but instead offers the primitives to enable snaps to manipulate the firewall for which the ufw snap provides an example[37].

Network interfaces

Ubuntu Core does not currently support fine-grained network mediation (eg, for per-snap access to IPv4 and IPv6 TCP and UDP ports) and snaps specifying the '`network-bind`' interface and providing network services are reachable by other snaps on the host (provided the connecting snap uses the client '`network`' interface) and over the internet. Applications may of course be programmed to bind only to the loopback network interface but this is not enforced by security policy. Authors desiring the system to perform fine-grained mediation to specific snaps should consider using either UNIX sockets or a DBus service at this time. Application developers may of course choose to implement access controls (eg, tokens, pre-shared key, username/password, etc) with their snaps as part of their network communication protocol to limit access and/or employ firewalling in their snaps.

Future versions of Ubuntu Core:

- Will support fine-grained network mediation to support scenarios such as assigning a network interface to a particular snap or allowing a snap to bind to a particular port
- Will enforce the concept of internal ports (via packaging yaml). Traffic to/from internal ports will (in essence) have the network packets tagged with the security policy ID so that inter-snap communication via network sockets (eg, IPv4/IPv6 TCP and UDP) will be mediated by security policy.
- Will support enabling default deny ingress filtering to the host with integration of external ports (via packaging yaml)

Logging

Ubuntu Core shares the same logging scheme as classic Ubuntu (see above). The only notable differences are that '`auditd`' is not currently available on Ubuntu Core images, logging customization is limited and Ubuntu Core uses systemd's '`journalctl`' command to obtain snap-specific logs. journald is configured for ephemeral logs with persistent logging via rsyslog. rsyslog can be disabled with '`snap set core service.rsyslog.disable=true`'.

In addition to standard system logs, Ubuntu Core provides the '`snap changes`' command to view snap installs, removals, and interface connects/disconnects with more information being added in future OS snap updates.

[37] A simple example might be to create a snap with a service to load a firewall with iptables-restore on start and save it with iptables-save on stop.

Ubuntu Core has tools that can be used to view and monitor sandbox denials (e.g. the ‘`snappy-debug`’ snap). Please see the [online documentation]() for details.

Clock synchronization

Ubuntu Core uses ‘`systemd-timesyncd`’ for time synchronization with remote NTP servers and it is enabled by default. Future updates to the core snap will allow configuration of the time servers via ‘`snap set`’.

Data encryption

The Ubuntu Core base system does not provide data encryption functionality, however snaps are free to manage encrypting their application data as desired. Future versions of Ubuntu Core will support data encryption options for promptless authentication and user login authentication.

Trusted Platform Module

Canonical provided kernels for Ubuntu Core include kernel support (`CONFIG_TCG_TPM` and `CONFIG_HW_RANDOM_TPM`) that can be used with snaps (eg, the ‘`tpm`’ and ‘`tpm2`’ snaps) that provide TPM userspace support. TPM is not currently integrated into Ubuntu Core beyond the ‘`tpm`’ interface, kernel configuration and the availability of the tools with snapcraft, but future versions of Ubuntu Core may incorporate the use of TPM as part of device identity, measurement and data encryption if the hardware supports it.

Solution

Ubuntu Core is an important revolutionary step for Ubuntu. While it builds upon the tradition of Ubuntu, applications are at the forefront and the system has many important features to support predictability, reliability and strong security guarantees.

Developer velocity and control

Ubuntu Core’s app-centric view and trust model puts control in the hands of publishers by decoupling snaps from the system. Application developers don’t have to wait for a new release of the Ubuntu distribution to get their latest features to users. Developers publish their applications to the store to have the snap available to devices on whatever timeline makes sense for them. They also don’t have to worry about unpredictable changes to the system and can avoid problems caused by untested package combinations.

Developers can still take advantage of the vast Ubuntu archive if they want. By building applications on Ubuntu, all of the Ubuntu toolchain hardening benefits are present and when using snapcraft, developers can bundle Ubuntu archive debs in their snaps. Snapcraft also allows developers to quickly rebuild their snaps with the latest debs containing security updates published by the Ubuntu Security team.

Safe, reliable updates for all devices and images

Keeping a system up to date is paramount to good system security and Ubuntu Core's update mechanisms are robust and safe. A problem with an application upgrade won't cause other application or system upgrades to halt. Snap updates are smaller due to delta upgrades and systems can run completely unattended to receive application and system updates automatically, rebooting as necessary. If there is a problem, the system also provides rollback mechanisms.

Canonical provides several supported reference kernels and also supplies the Ubuntu Core OS snap, reference gadget snaps and reference images for anyone to use. All of these parts receive official security support from Canonical. Vendors can partner with Canonical for vendor kernels, gadget snaps and store branding to meet the flexibility needs of any project. Canonical maintains the OS snap and kernel snaps (reference or in partnership) while developers, OEMs and ISVs focus on their applications.

Security provides assurances

In addition to reliable updates, Ubuntu Core provides strong security assurances because the system is designed with security in mind. The system design, store policies and security sandboxing protect the system from tampering, sensitive system information disclosure and data theft from subverted or misbehaving applications. Developers can also rely on a stable system for their applications and not worry about unpredictable changes causing instability or security problems.

Continued flexibility

Ubuntu Core also provides flexibility. Snaps can ship multiple services and commands that can freely interact with each other and the system provides convenient methods for safe hardware access. Snap interfaces can be used to connect snaps and snaps work together with the public publisher Snap Store and brand stores to enable and foster any number of ecosystems.

Conclusion

No longer do devices have to run outdated software; no longer do software vulnerabilities have to result in system compromise or data theft; no longer do vendors have to endure the maintenance headaches of rolling their own custom OS. Ubuntu Core gives you the freedom and assurances to build robust and secure products for the world to consume and provides you assurances that the system will operate reliably, predictably and securely.